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PRELIMINARY REPORT ON IRON ORE DEPOSITS NEAR WHITE SULPHUR SPRINGS, MEAGHER COUNTY, MONTANA, BY G. E. GOODSPEED

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PRELIMINARY REPORT

ON

IRON ORE DEPOSITS NEAR WHITE SULPHUR SPRINGS

MEAGHER COUNTY, MONTANA

G. E. Goodspeed

ABSTRACT

The iron deposits near White Sulphur Springs are of two types: (1) those to the north, the limonite-hematite deposits adjacent to Sheep Creek; and (2) those to the southeast, the magnetite deposits in the Castle Mountains. In the Sheep Creek area the evidence indicates that shales of the Belt ~~formation~~ series have been locally replaced by limonite, hematite, and jasperoid quartz. Averages of analyses show that the ferruginous material ranges from 27.98 percent iron to 43.88 percent iron. The possible position of the ferruginous members is shown on a generalized cross section, but due to indeterminate factors concerning the actual extent no tonnage estimates are given. The magnetite deposits in and adjacent to the Castle Mountains are briefly described. One of them, the Ringling property on Willow Creek a few miles southeast of White Sulphur Springs, is estimated to contain 187,000 tons of inferred ore.

INTRODUCTION

The iron ore deposits near the town of White Sulphur Springs, Meagher County, Montana, may be grouped into two contrasting types. They are: (1) the limonitic deposits of the Sheep Creek area some 15 miles airline north and slightly west of the town, and (2) the magnetite deposits in and adjacent to the Castle Mountains a few miles to the southeast of the town.

White Sulphur Springs, named from several local, hot, sulphur springs, is situated in the Smith River valley at an elevation of 5000 feet about 20 miles to the southwest of the Little Belt Mountains and 9 miles northwest of the Castle Mountains and is on the Yellowstone-Glacier National Park highway about 110 miles south of Great Falls (Fig. 1). It is the county seat of Meagher County, the principal trading and population center of the immediate region. A branch line of the Chicago Milwaukee Railroad terminating there connects it with the main line at Ringling, Montana.

The iron ore deposits near White Sulphur Springs were examined during the summer of 1943 by the writer assisted by Mr. J. P. Fitzsimmons. In the Sheep Creek area two weeks were spent in mapping most of Section 34 on a scale of 200 feet to the inch and a contour interval of 20 feet (plate 1). A complete suite of specimens from this area, as well as selected specimens from the other deposits, furnished material for laboratory studies of thin sections and polished sections.

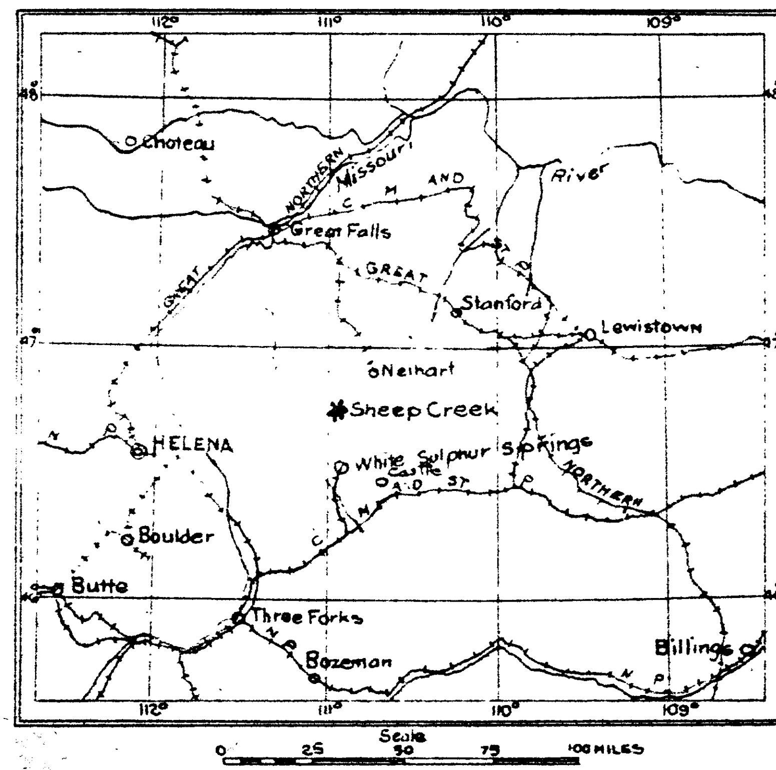

Figure I Index map showing the location of White Sulphur Springs and Sheep Creek

A considerable part of the exploratory and development work on the iron deposits near White Sulphur Springs was done over 20 years ago and some of the workings are still accessible. Production records, if there was any production, are lacking. Some churn drilling was done about this time on the Sheep Creek deposit, but logs are not available.

In the fall of 1943, the Bureau of Mines made a map of the Sheep Creek area to have a grid for the location of 23 churn drill holes to prospect most of Section 34 with the holes spaced from 800 to 1000 feet apart. This map was incorporated with the previously mentioned topographic and outcrop map of the Geological Survey. During the fall of 1943 and the spring of 1944 the Bureau of Mines drilled the 23 holes totaling 1159 feet; excavated 9 bulldozer trenches totaling 1050 linear feet; and took 432 samples for chemical analyses.

The topography of the rolling hills of the Sheep Creek area is in marked contrast to that of the isolated, dissected Castle Mountains. According to Weed 1/ the Sheep Creek area consists of pre-Cambrian and Cambrian sedimentary rocks invaded by a few small bodies of igneous rock and structurally forms the southwest flank of the Little Belt Mountains. The Castle Mountains consist of a mass of granite, 4 by 7 miles in extent, which has intruded pre-Cambrian, Paleozoic and Mesozoic sedimentary rocks. The iron ore deposits in the vicinity of the Castle Mountains, predominately magnetite, occur near the contact of the intrusive mass and the sedimentary or metamorphosed sedimentary rocks. The limonitic ores of the Sheep Creek area do not appear to have any direct connection either genetically or structurally with the small intrusive igneous masses occurring just southwest of the mapped area of Section 34.

IRON ORE DEPOSITS IN THE VICINITY OF SHEEP CREEK

Location and ownership

Most of the iron deposits in the vicinity of Sheep Creek are located in Sec. 34, T. 12 N., R. 6 E. which is about 2 miles southwest of Sheep Creek, and nearly 1 mile southwest of Black or Coxcomb Butte. This area is drained by Butte and Copper Creeks, tributaries to Sheep Creek which heads in the Little Belt Mountains some 14 miles to the northeast. The iron deposits may be reached from White Sulphur Springs by travelling north over the Yellowstone-Glacier National Park highway (State highway 89) approximately 19 miles, then turning west along a dirt road for about 4 miles.

1/ Weed, W. H., The Little Belt Mountains Quadrangle, Folio Geological Atlas, U. S. Geol. Survey, 1898.

The following claims are owned by E. K. Coyner of Marion, Virginia:

Patented Claims	Unpatented Claims
Flanagen	Lion
Blackstone	Limonite
Central	Hematite
Bear	Miller
Hobbs	Roanoke
Welch	Harris
Vulcan	Pulaski
Copper	Big Butte
Iron Cliff	
Black Butte	
Richmond	

In 1943-44, Yellowstone Metals, Incorporated, of Billings, Montana, held an option on this property.

The property has no improvements. All necessary buildings, if operation were contemplated, would have to be built by the operators. Timber is locally available. One of the trunk power lines of the Montana Power Company passes within 10 miles of the property. Although limestone occurs in the vicinity of Sheep Creek, coal would have to be obtained from Belt, Montana, 80 miles to the north; and coke from Fernay, British Columbia, about 600 miles by rail from White Sulphur Springs. If warranted, a rail spur could be laid on a water grade from White Sulphur Springs to the property.

General Geology and Description of Sedimentary Rocks

The area which includes most of the iron deposits (plate 1) has an elevation of about 6,000 feet with a maximum relief of 568 feet. Moderate grassy slopes prevail over most of the area (Sec. 34) although some parts are covered with a sparse to thick growth of pine, and in the southwest part the trees are aspens. The most prominent topographic feature in the vicinity is Coxcomb or Black Butte, a jagged erosion remnant of steeply dipping quartzite rising about 1000 feet above the surrounding country and is in marked contrast to the rolling hills of this particular area.

As part of the Little Belt Mountains Quadrangle, this area was mapped by Weed 2/ as "Belt formation" (Belt series) and Coxcomb Butte as Cambrian. However, Weed 3/ states that its age is uncertain and that it may be a part of the "Belt terrane." The prevailing rocks are thinly bedded shales,

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2/ Op. Cit.

3/ Weed, W. H., Geology of the Little Belt Mountains, Mont. U. S. Geol. Survey. Twentieth Annual Report, Part III, 1898-99, pp. 271-461, 1900.

arenaceous shales, ferruginous shales, arenaceous limestones, jasperoid rock, and limonitic beds with a limited amount of hematitic beds. There are a few small outcrops of shale and limey shale but the principal exposures of these rocks are in old cuts and shafts. The churn drill logs furnish additional geologic information, but they lack the accuracy of diamond drill cores.

Judging from the attitude of the few exposures, from the logs of the churn drill holes, and from outcrops in adjacent areas it is probable that the structure is a relatively gentle anticline with its axis trending in an east-west direction through the central part of the area.

A characteristic specimen of the light brown shales of this area is compact, fractures fairly smoothly parallel to the bedding, shows find but indistinct stratification planes, and effervesces slightly with dilute HCl. A few, very minute, quartz grains are barely discernable with a hand lens. Some of the stratification planes are very light brown and somewhat pinkish in color. The lighter colored bands appear to have a higher concentration of lime carbonate than the darker ones which are no doubt richer in iron oxide. A few small veinlets (0.5 mm. wide) of calcite and several narrower veinlets of limonite transect the shale at right angles to the bedding.

In thin section, this rock is seen to consist of about 5 percent angular to subangular quartz grains of 0.05 mm. average size, some irregular aggregates of carbonate of about the same size, a few shreds of biotite 0.04 to 0.06 mm. in length, and a few round or irregular patches of limonitic material 0.02 mm. in size, in a very fine matrix of brownish, kaolinitic material with some carbonate and indeterminable detrital grains 0.005 mm. in size. One edge of this thin section shows part of a veinlet filled with allotriomorphic granular calcite and bordered with limonite.

Owing to their finely-bedded nature, many of the shales of this area break into tile-like fragments a fraction of an inch to an inch thick. Some of the arenaceous shales contain small rounded and elongated chert fragments which are in rough alignment parallel to the bedding. As measured in thin section a few of these fragments are seen to be 2 mm. long and 0.25 mm. thick. Several of them are subangular in outline. Although some of the chert fragments may be detrital in origin, others appear to be authigenic in that they exhibit gradational boundaries with the fine matrix of the shale and also include numerous minute angular grains of detrital quartz. The matrix is a very fine aggregate of kaolinitic material stained slightly brown with limonitic material and contains numerous, angular, detrital grains of quartz which are 0.04 mm. in size. From the standpoint of the iron ores it is of interest to note that the thin section of this shale reveals rounded, elongated, or irregular patches of concentration of limonitic material from 0.08 to 1.0 mm. in size. Some of these have very irregular borders, others are veinlike in the matrix or between the chert fragments, and a few penetrate and appear to have partially replaced the chert. However, a few very narrow (0.01 mm. or less) veinlets of later, fine-grained silica transect the limonitic patches, the chert fragments and extend into the matrix of the shale. In other words this light gray shale which has a micro-structure resembling an intraformational breccia shows an incipient concentration of limonitic material.

The arenaceous, shaly limestone is compact, almost black, contains several, minute, quartz grains and has a fine stratification. It is jointed in such a manner that rectangular slabs are common, and weathers to a light buff color along the joint cracks. In thin section under the microscope this limestone is seen to consist of about 3 percent detrital quartz grains, 0.04 mm. in size, in a matrix of finely granular (0.01 mm. and less) carbonate with a few irregular patches of carbonaceous material.

Soft, light colored shale crops out near the portal of an old caved tunnel on the eastern part of the Roanoke claim. The shale, which is apparently nearly flat lying, exposed in cuts to the east of the tunnel, is slightly iron stained. The most noteworthy feature of this shale is its light weight and porosity. It is filled with numerous irregular minute pores, is light gray, finely bedded and has narrow indistinct bands slightly darker in color parallel to the stratification. A sawed surface of the rock shows numerous small, thin, slightly curved, elongated fragments which are parallel to the bedding. The shape and the white appearance of these fragments as well as the rough feel of the powdered rock suggest a volcanic ash origin, but under the microscope these fragments are seen to be chert. Their average size is 0.5 mm. by 0.1 mm., with some over 2 mm. in length. Numerous, angular, detrital grains of quartz, 0.04 mm. and less in size, are distributed through the fine kaolinitic matrix and included in some of the so-called chert fragments or segregations. An occasional shred of muscovite and a small amount of ferruginous material is present and in crushed fragments a few grains of plagioclase and minute grains of minerals with high indices of refraction are distinguishable. The soft, porous shale is of special interest in relation to the iron deposits of the area, clearly indicating that the shale's permeability coupled with fineness of grain would make it particularly susceptible to the circulation of solutions.

Character of the Iron Deposits

Three types of iron deposits occur in the vicinity of Sheep Creek:

A. Steeply dipping fracture zones or veins which transect the sedimentary beds. Hematite and limonite are the chief ore 4/ minerals. Jasperoid quartz with some earlier, coarse-grained, vein quartz are the gangue minerals.

B. Replacement deposits of limonite with some hematite

4/ The word "ore" is not used in this report in its economic sense, but is used to describe the ferruginous material which under more favorable conditions (increased quantity, greater purity, etc.) would constitute an ore in an economic sense.

parallel to the bedding of certain members of the sedimentary series. The strata are commonly flat lying or gently dipping.

C. Detrital boulders of limonite and hematite.

It is probable that there is a type which is intermediate between the first two types listed above (A&B), i.e., a lateral replacement from the steeply dipping fracture zones or veins.

Two prominent outcrops of iron ore, one on the Iron Cliff claim, and the other on the Vulcan and Richmond claims are representative of the fracture zone or vein type of deposit. In parts of these outcrops there are what appear to be nearly vertical fracture planes in the ore, but not later than the ore. Here the presence of contorted and brecciated zones completely replaced by iron oxide or jasperoid quartz but showing distinct relics of the original sedimentary material indicates that these fracture zones were the channels for the solutions which deposited the hematite, limonite, and jasperoid silica. In other words these cross-cutting, steeply dipping, fracture zones appear to be in the order of replacement veins; and although some filling may have taken place, they probably should not be classed as filled fissure veins. Some thin sections show numerous relics of earlier coarse grained vein quartz transected by veinlets of hematite, geothite, and limonite and replaced by these minerals, and some contain small detrital grains of quartz in the ore minerals. A specimen from one of the brecciated fracture zones consists chiefly of angular fragments (10 to 20 mm. in size) of dense, gray hematite in a matrix of red hematite and yellow limonite. A polished section shows that the dense, gray, earlier hematite is transected by and partially replaced by the later hematite and limonite. A few, minute, irregular cavities are visible both in the fragments and in the matrix of the breccia. In a thin section of the breccia a few, very narrow veinlets of what is apparently opaline silica with a little carbonate are present.

Data derived from the trenches made by the Bureau of Mines show that these veins are very irregular along strike and that the indicated tonnage is small. The Bureau computes analyses of channel samples across the veins only, to average 46.5 percent iron, 20.8 percent silica, 0.32 percent sulphur, and 0.38 percent phosphorus. Vein material of this quality constitutes only a small fraction of the total footage trenched and sampled (see Appendix A and hole No. 20A).

In some parts of the iron ore outcrops, as well as in numerous cuts, shafts and tunnels, bands of limonite, hematite, and jasperoid quartz range in thickness from a few inches to 15 or 20 feet. The bands are parallel to the nearly flat-lying shales and commonly contain relics of bedding suggesting that a lateral permeation of iron rich solutions has taken place. A further substantiation of this interpretation is the gradual thinning of the bands of iron ore away from the steeply dipping fracture zones, until only local horizontal and vertical fractures in light brown shale are filled with limonite, and then, finally, at a still greater horizontal distance from the fracture zones the shale becomes light gray in color with hardly a trace of ferruginous material.

Thin sections and polished sections of this type of banded iron ore show angular quartz grains comparable in size, (0.04 to 0.05 mm.) and in amount to the detrital quartz commonly contained in the shales.

Numerous exposures of horizontal bands of iron ore in some of the cuts, shafts and tunnels do not show any direct relationship to the steeply dipping, cross-cutting fracture zones. However, it is possible that such connections are not exposed or have been eroded subsequent to the formation of the iron ore. In these banded deposits the ore varies from porous breccias to compact, limonitic, chert breccias to massive limonitic or hematitic material.

The compact, limonitic, chert breccias consist of yellow, tabular fragments of cherty limonite cemented by a matrix of darker colored limonitic and hematitic material. The fragments range in size from a fraction of an inch to more than an inch in length and width, and from 1/8 to 1/2 inch in thickness. They are usually in alignment parallel to the bedding, but in some breccias they are inclined to the bedding at varying angles and appear to be broken chert-like bands.

The porous breccias are similar to those just described except that they contain many openings ranging from minute irregular pores parallel to the bedding to irregular and angular openings between the fragments. These openings are about the same size as the fragments. Considering the amount of pore space in these rocks they are not as friable as might be expected and some are fairly tightly cemented with iron oxide and jasperoid silica.

In some exposures the massive type of bedded iron ore grades into the breccias while in others sharp borders prevail. Although traces of the original bedding remain in most of the bedded ore, some that is very massive breaks with a conchoidal fracture and shows but a few relics of the bedding. Ore of this type probably has a high content of jasperoid silica. Even in this massive limonite and hematite of the bedded ore a few minute, thin irregular pores are occasionally present. Some of these pores are parallel to the traces of the bedding while others are normal to or at angles to it.

It is estimated from data furnished by the Bureau of Mines that the average iron content of the bedded breccias is 39 percent and the silica, 21 percent, and that the average iron content of the massive ore is 43 percent and the silica, 21 percent. These data also provide the information that the silica in the massive ore is distributed in sizes ranging from -20 to -200 mesh and that both the breccias and the massive types of ore contain too much sulphur and phosphorus for use as blast furnace feed.

Thin sections and polished sections of the bedded iron ore show wide variations in ore mineral content but a striking uniformity in the presence of minute grains of detrital quartz which are commonly distinctly aligned with the bedding. Limonite is the dominant ore mineral in some of the sections, while others contain a mixture of hematite and yellow limonite with some reddish mineral that may be lepidocrosite. Veinlets of goethite that are parallel to, and cross the bedding are present in some of the sections. Also noticeable in some of the sections is an irregular penetration of hematite parallel to the bedding and showing indistinct borders with the limonite. Hematite commonly obliterates the original microstructures of the shale although detrital grains of quartz are usually clearly discernable in the denser textured material. Jasperoid quartz is intimately associated with most of the ore and also occurs in minute veinlets.

As previously noted, detrital quartz is present in all the sedimentary rocks; and in some of them, small chert fragments or chert segregations and the incipient concentration of limonitic material are noticeable. Another noteworthy feature is the very evident porosity and permeability of even some of the very fine-grained types. Hence the ubiquitous occurrence of detrital quartz and the relic microstructures, especially traces of original bedding, in the iron ore suggest that iron-rich solutions locally permeated and selectively replaced the greater part of the original sedimentary rock with limonite or hematite and jasperoid quartz. There is no indication that the limonite is the product of oxidation of earlier introduced sulphides. No sulphides and no traces of crystal outlines of previously existing sulphides were seen in any of the sections examined. Since the delicate microstructures of the original shale are preserved in the limonitic ore it would be expected that if sulphides had been present some traces of their crystal outlines would remain.

It is possible that some of the porous breccias represent an incomplete stage of the replacement process in that the removal of soluble material in the matrix between cherty bands exceeded the deposition of iron oxide and that local dislocations of these bands produced the brecciation. Some of the finely porous limonitic beds may have been produced by a similar mechanism accompanying the replacement of thin bedded shales. Other breccias of the bedded ores may have been originally intraformational breccias. Field and petrographic evidence does not indicate that the bedded ore breccias were originally or contemporaneously cataclastic breccias.

On the slopes below the iron ore outcrops are numerous, detrital boulders of iron ore, and in many of the cuts scattered over the property angular flatish pieces of ore and jasperoid rock, ranging from a few inches to a foot or more in size, occur under a cover of about a foot of top soil. In some cuts these tabular detrital boulders are closely packed to a depth of several feet, while in others only a few are to be seen. The detrital boulders of iron ore have been derived from both the vein and the bedded type of deposit since they exhibit features characteristic of both types. Before the exploration work was done, it was thought that the detrital boulders would form a considerable tonnage of iron ore which could be cheaply mined. However, exploration by the Bureau of Mines has shown that the iron ore boulders are confined mainly to the upper few feet of the overburden and are not uniformly distributed areally. Therefore the tonnage of this detrital ore is probably small.

Reserves

The two principal iron ore outcrops shown on the map (plate 1) are in part the vein form of hematite-limonite and in part the lateral replacement of adjacent, nearly flat-lying shales by the iron ore minerals hematite and limonite and by jasperoid quartz. Even if the lateral replacement type has a maximum thickness of 20 feet the exploratory work has shown that the veins are very irregular along their strike so that tonnage is small.

An interpretation of the structure of the sedimentary rocks of the area based on the few outcrops, on the exposures in the cuts and shafts, and on the data from the churn drill holes is given in the generalized cross sections (plate 2). It is to be noted that the ferruginous shale which is locally replaced by hematite and limonite appears to be the most important iron member, but that the local variations of the hematite and limonite both in stratigraphic thickness and in lateral extent are pronounced. This condition is indicated in the generalized cross section by the interfingering and thinning out of the ferruginous shale with respect to the other shales. Some of the other shales are locally ferruginous, calcareous and cherty, and some are cherty ferruginous shales, but here again numerous local variations in iron content prevail. It is possible that these bedded replacement deposits are genetically related to vein types which are not exposed or the connections to which have been eroded.

Although erosion has removed some of the vein and bedded material, yet the exploratory work does not indicate any significant tonnage of detrital boulders of hematite, limonite, or jasperoid rock in the overburden.

Some of the chemical analyses are shown on plate 2 and other analyses are given on page 10 and in appendix A of this report. The Bureau of Mines Experiment Station at Salt Lake City made ore dressing tests such as log washing, sink-float, jigging and tabling and found that the Sheep Creek material could not be beneficiated. Although in a sponge iron test there was some reduction in sulphur content the rejection of insolubles was poor.

The following analyses by the Bureau of Mines are from samples taken before their exploratory work on the property.

Location	Sample No.	% Iron	% Insol.	% Sulphur	% Phosphorus
Smith ranch, tunnel 5.5'	172	34.72	37.68	0.110	0.064
Pit east end Richmond	173	40.16	33.40	0.060	0.084
Vulcan hole #1	174	52.83	14.02	0.126	0.080
Vulcan hole #2	175	51.00	19.16	0.048	0.066
Vulcan hole #3	176	45.13	20.00	0.048	0.054
Central D-2	177	48.18	16.24	0.051	0.035
Central #1 shale	178	36.97	35.38	0.055	0.014
Harris T-1	179	45.83	25.36	0.043	0.030
Roanoke pit #1	180	46.53	20.74	0.043	0.085
Bear pit S-1	181	50.93	12.96	0.057	0.037
Average		45.23	23.49	0.064	0.055

In its exploration the Bureau of Mines prospected rather thoroughly sec. 34, T. 12 N., R. 6 E. Four separated, small areas constituting a very small portion, 1 to 2 percent, of this section were found to be underlain by ferruginous shale of varying thickness assaying 20 percent iron or better. From analyses of trench and drill hole samples the Bureau has estimated that slightly less than half of this material (4,953,000 long tons) assays: 43.88 percent Fe, 20.68 percent SiO_2, 0.70 percent S, nd 0.035 percent P; slightly more than half (6,560,000 long tons) of it assays: 27.98 percent Fe, 35.04 percent SiO_2, 0.35 percent S, and 0.052 percent P. It will be seen from these analyses and from the fact that the material cannot be beneficiated, that under existing economic conditions, the deposit cannot be considered to contain ore in its economic sense.

The geologic and petrologic evidence clearly indicates that the dominant process of formation of the Sheep Creek deposit has been the replacement of either steeply dipping fracture zones or flat-lying beds of shale by iron rich, siliceous, hydrothermal solutions. These solutions were probably derived from a deep seated, and perhaps very deep seated, basic magmatic source; and not from any adjacent intrusive magmatic body. Both the vein and the bedded type of deposit are characterized by their irregularity in form and extent.

One of the aims of the drilling program completed by the Bureau of Mines was to see whether the detrital boulders were of sufficient amount and tenor to be considered ore in the economic sense and in this respect the results are negative.

Taking into consideration the unfavorable results of the geologic, analytic and other data now available and realizing that some of these data are inadequate, it is believed that tonnage estimates of iron ore in the Sheep Creek area are not warranted at this time.

Recommendations

Additional exploratory work would be justified only if at some future time it should become economically feasible to work the Sheep Creek deposit. At that time the vertical extent of the vein type of deposit and the position, thickness and lateral extent of the bedded types of deposit could be more accurately determined by diamond drilling. No additional work is recommended at this time.

RINGLING PROPERTY ON WILLOW CREEK SOUTHEAST OF WHITE SULPHUR SPRINGS

This iron deposit, formerly worked by Ringling Bros., is about 5 miles airline southeast of White Sulphur Springs on the east bank of Willow Creek a few hundred feet to the east of and about 150 feet above the creek. It is reached from White Sulphur Springs by travelling about three miles east on the Musselshell highway to the Smith ranch then south on dirt roads for about 4 miles.

The principal working on this property is a small glory hole (elevation 6000 feet), trending northeast-southwest, about 150 feet long, 50 feet wide, and 30 feet deep. Other workings, which are partially caved, consist of two tunnels and a raise which comes to the surface in the northern part of the glory hole. Bunkers at the portal of the lower tunnel are the only improvements on the property. Some ore has been shipped but no details as to tonnage or tenor are available.

Crystalline limestone, steeply dipping to the north, is above the ore in the northern and western part of the glory hole, and coarse-grained granite is exposed in the upper, eastern part of the glory hole where it also appears to be above the ore. The largest mass of iron ore crosses the northern part of the glory hole in an east-west direction and is in the form of a prominent ridge 10 feet wide at the top enlarging downward both to the north and south. The ore ranges from hard, fine-grained magnetite to an intimate mixture of magnetite and limestone, and locally to a soft, powdery, brilliant red hematite. In the central part of the glory hole some nodular masses of magnetite occur in brownish altered limestone. Just below this nodular ore on the western side of the glory hole are numerous slickensides some of which transect fine-grained magnetite with numerous small inclusions of limestone. Locally some of the magnetite is cut by coarsely crystalline calcite veinlets. Underground, a considerable amount of kaolinized rock and gouge is present adjacent to the ore.

The crystalline limestone has a fine, sugary texture and with the exception of a few brownish stains is nearly pure white in color. In thin section it is seen to consist chiefly of calcite and to have a xenoblastic texture with irregular interlocking grains of calcite (0.6 mm by 0.2 mm.) which show a rough alignment. Some scattered, rounded and irregular patches of fibrous, chalcedonic quartz and finely granular quartz appear to have locally replaced the calcite. A few, very minute, limonitic veinlets transect both the calcite and the quartz. Contact metamorphic minerals are not present.

The granite is coarse-grained and gray with chalky white feldspars intermingled with clear gray feldspar and quartz producing a speckled appearance. The feldspars range from 2 by 3 mm. to 4 by 8 mm. in size and in shape from subhedral to anhedral. A few small (1 to 2 mm.) euhedral crystals of biotite are present. Some of the quartz is similar in size to the feldspars and some shows a very fine, graphic intergrowth with feldspar. Some of the granite shows several irregular, angular cavities (1 to 5 mm.) which are commonly bounded by the crystal faces of adjacent feldspars. The granite shows a slight amount of limonitic staining probably due to weathering. Thin sections of the granite show a hypidiomorphic, granular texture with some micrographic intergrowth of quartz and orthoclase. The dominant minerals are orthoclase and quartz; subordinate, oligoclase and biotite; and accessories, titanite, a few small crystals of apatite, and an occasional grain of magnetite. The orthoclase is turbid owing to the presence of kaolinitic material while the oligoclase is relatively clear. Some of the oligoclase is included in the orthoclase and the ragged boundaries of the former with the latter indicate clearly that oligoclase has been replaced by orthoclase. Biotite has been replaced in part by orthoclase. Quartz exhibits boundaries suggesting that it has partially replaced all of the earlier minerals and the evidence for replacement is particularly clear with respect to the micrographic intergrowth of quartz and orthoclase.

It seems probable that the granite was formed by deuteric action from an originally more basic magma. This interpretation would explain the peculiar enveloping nature of the altered orthoclase, the presence of open cavities and the coarseness of grain as well as the alteration. Such a deuteric magma might crystallize at a relatively low temperature and hence high temperature, silicate minerals would not be expected in the adjacent crystalline limestone. It is also improbable that a silicic, potassic magma could furnish sufficiently iron-rich emanations to form the adjacent bodies of iron oxides.

Reserves

Owing to the lack of exploratory work and to the inaccessibility of some of the workings it is not possible to estimate either measured or indicated ore. However, judging from the surface and underground workings and on the assumption that the ore body is 150 feet long, 50 feet wide and 200 feet in vertical extent, it would contain 187,600 tons of inferred ore. No data are available regarding the tenor of the ore, but it is probably fairly high-grade although locally it grades into crystalline limestone.

Some of the high-grade, massive iron ore is very fine-grained and contains numerous, small, irregular inclusions of limestone slightly stained with limonite. In polished section this ore is seen to consist of a very fine-grained aggregate of magnetite with some very minute crystals of specular hematite. In both the thin section and the polished section the magnetite shows crystal faces against the calcite or cusp-like boundaries with the convex part of the cusps toward the calcite. These features, in addition to a few, short, transecting veinlets of magnetite indicate a replacement mechanism of formation. Another specimen of the massive ore has a similar appearance except that the limestone inclusions are larger (5 mm.), and that in polished section the fine-grained magnetite is seen to be finely brecciated with the matrix consisting of fine-grained, reddish hematitic material.

More evidence in favor of replacement as the dominant mechanism of formation of this deposit is revealed by the transition of massive ore into limestone. The transitional material ranges from finely crystalline, slightly brownish limestone containing disseminated, irregular patches of magnetite, to an intimate mixture of limestone and the ore mineral. Thin sections and polished sections exhibit features such as the minute penetration of magnetite into calcite, interlocking veinlets of magnetite, and the inclusion of relic material in the magnetite. Some of the sections show a partial replacement of the limestone by chalcedonic quartz previous to the replacement by magnetite.

Sufficient data are not available to outline in detail the structural control for the formation of the Ringling deposit. However, the presence of slickensides and of extensive kaolinization and gouge at depth coupled with the petrologic evidence, indicates that the iron ore was formed by iron-rich, hydrothermal solutions rising along fractured and fissured zones, and that the replacement of limestone by the ore minerals was the dominant mechanism of formation.

Recommendations

If further exploratory work should be contemplated for this property, it would be advisable to have a magnetometer survey made before the work is done.

MISCELLANEOUS IRON DEPOSITS IN THE CASTLE MOUNTAINS

The following iron deposits were examined August 5, 1943, during the course of a reconnaissance trip through the Castle Mountains, incident to the iron ore investigations in the vicinity of White Sulphur Springs.

Claim of J. E. Hensley of Castle, Montana

This claim is located on Hensley Creek just east of the Bell property, a sulphide replacement deposit, about 3 1/2 miles west of north of the old town of Castle. One cut exposes 15 feet of fine-grained magnetite mixed with sulphides. The deposit is near a contact of syenite porphyry and metamorphosed sedimentary rocks.

Queen Property

The Queen property is situated just north of the Bell property. According to Mr. Hensley, a tunnel, now caved, intersected 50 feet of iron ore and a drift from the tunnel exposed 75 to 100 feet of ore. He also stated that in 1902 about 2000 tons of ore, at $4 per ton, were shipped from the property to East Helena for use as a flux. Analyses of the ore from this property were made by the American Smelting and Refining Company of East Helena and are as follows:

Percent Iron	Insol.	Percent Mn	Percent Sulphur
61.5	8.9	1.0	Trace
53.9	11.9	0.7	0.2

Percent Iron	Silica	Percent Cu	Percent Pb	Silver Oz.
53.4	10.0	2.3	Trace	1.0
56.8	6.4	0.6	0.8	0.3
55.0	11.6	1.0	1.0	0.8

This property is also near a contact of porphyry and metamorphosed sedimentary rocks.

Iron Chief Property

This property is located about a quarter of a mile to the south of the site of the former town of Robinson. It is owned by Mrs. Maery Wilson of Roundup, Montana, and was a part of the old Two Dot estate.

One conspicuous east-west trending outcrop about 60 feet long, 25 feet wide and 20 feet high is the only natural exposure on the property. The ore is fine-grained magnetite and is associated with jasperoid quartz. Cherty, jasperoid quartz occurs on the top of the outcrop and is exposed in a cut about 30 feet south of the outcrop. Some iron ore and jasperoid quartz is exposed on the side of a cut about 200 feet to the east of the outcrop and near the old workings of a lead property. Although no rock outcrops are to be seen in the immediate vicinity, it is possible that this iron ore deposit is adjacent to a contact of limestone and porphyry.

Recommendations

A magnetometer survey should be the first step for these properties if any further exploratory work were contemplated.

APPENDIX A
ANALYSES OF BUREAU OF MINES TRENCH SAMPLES

Trench B.T. 1

Sample	% Fe.	% S.
0 - 5	9.19	
5 - 10	5.53	
10 - 13	16.28	
13 - 15	7.60	0.012
15 - 19	20.90	0.044

Trench B.T. 2

Sample	% Fe.	% S.
0 - 5	12.50	
5 - 10	30.78	
10 - 15	22.78	
15 - 20	18.48	
20 - 25	22.00	
25 - 30	19.59	
30 - 35	14.60	
35 - 40	18.58	

Trench B.T. 3

Sample	% Fe.	% S.
0 - 5	10.50	
5 - 10	12.50	
10 - 15	23.98	

Old Trench

Sample	% Fe.	% S.
0 - 5	50.08	
5 - 10	48.48	
10 - 15	52.00	
15 - 20	50.00	
20 - 25	52.85	
25 - 30	56.13	
30 - 35	54.61	
35 - 40	54.16	
40 - 45	54.97	
45 - 50	53.10	
50 - 55	53.40	
55 - 60	56.21	

Trench B.T. 4

Sample	% Fe.	% S.
0 - 5	8.16	
5 - 10	14.79	
10 - 15	32.70	
15 - 20	35.46	
20 - 25	37.52	
5 - 30	54.30	
30 - 35	48.82	

Trench B.T. 5

Sample	% Fe.	% S.
0 - 5	22.82	
5 - 10	39.40	
10 - 15	42.60	0.085
15 - 20	46.74	0.16

Trench B.T. 6

Sample	% Fe.	% S.
0 - 5	41.00	
5 - 10	38.93	
10 - 11.5	44.50	
11.5 - 15	37.84	
15 - 20	34.50	
20 - 25	39.28	
25 - 30	33.94	
30 - 35	38.62	
35 - 40	39.58	
40 - 45	41.54	
45 - 50	40.50	
50 - 55	40.48	
55 - 60	39.46	

Trench B.T. 7

Sample	% Fe.	% S.
0 - 5	42.18	0.24
5 - 10	39.46	0.25
10 - 15	44.10	
15 - 20	52.09	
20 - 25	53.18	
25 - 30	50.99	
30 - 35	45.70	
35 - 40	38.99	

Trench B.T. 8

Sample	% Fe.	% S.
0 - 5	5.05	

Trench B.T. 9

Sample	% Fe.	% S.
0 - 5	6.12	